SYNCHRONIZED VIBRATION DEVICE FOR HAPTIC FEEDBACK

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of the filing date of U.S. Provisional Patent Application No. 60/694,468 filed Jun. 27, 2005 and entitled SYNCHRONIZED VIBRATION DEVICE FOR HAPTIC FEEDBACK, the entire disclosure of which is hereby expressly incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0002] This invention is generally related to vibration devices. Applications include devices such as those that produce haptic sensations to enhance the realism of a video game, vibratory parts feeders, and vibration shakers.

[0003] Actuators that provide force feedback and haptic sensations are used for a wide range of applications including gaming devices, medical simulators, and flight simulators. Actuators in haptic devices create force sensations which are felt by the user.

[0004] One method for generating a haptic sensation is to use vibratory actuators such as those described in U.S. Pat. Nos. 6,275,213 and 6,424,333. Vibratory actuators provide a low cost method for generating force sensations, and multiple vibratory actuators can used to generate a range of sensations. In many existing devices vibrations are generated through rotary motors with an eccentric mass.

[0005] A limitation of eccentric mass rotary vibrators is that under continuous vibration the force of vibration is coupled to the magnitude of vibration, and thus it is not possible to modify the magnitude of vibration for a given vibration frequency. Another limitation of existing vibration devices is that the direction of vibration force is set by the orientation of the vibration actuators, and cannot be modified during operation.

[0006] In existing devices there is minimal or no directional information is provided to the user, and the force sensations are limited to the frequency of vibration of the actuators. In existing vibration devices with multiple vibration actuators, there is typically no synchronization of the vibration waveforms of the various actuators, and the phase difference between the different vibrations is not explicitly specified or controlled. This lack of synchronization limits the types of force effects that existing vibration devices can generate.

[0007] One application of vibration devices is in haptic input devices such as game controllers. Haptic devices use force to convey information to the user. In computer games and other applications it is desirable to convey a wide range of information to the user through force including frequency, magnitude, and direction of force. Since existing vibration devices do not convey all such information, there is a need to provide increased range of force sensations using vibratory actuators.

[0008] Existing tactile vibration devices often use small motors. These motors exert a low magnitude of force, and often require a number of vibration cycles before they build up sufficient force magnitude to be felt. Thus, many existing vibration devices provide tactile sensations that can only be felt at high frequency vibrations, where vibration energy can be built up over time. However, it may be desirable to also generate low frequency sensations to correspond to events that occur at a lower frequency than the vibration frequency. Thus there is a need to generate low frequency force sensations will small actuators.

SUMMARY OF THE INVENTION

[0009] The present invention provides a wide variety of vibration devices, haptic interfaces, game controllers and vibratory control systems.

[0010] One example of a vibration device of the present invention comprises of a plurality of vibration actuators that are synchronously vibrated. The actuators may be linear motion vibration actuators. In one alternative, the linear motion vibration actuators each include a moving magnet and a stationary electromagnetic coil. In another alternative, the linear motion vibration actuators each include a moving ferromagnetic plunger and a stationary electromagnetic coil. In a further alternative, the linear motion vibration actuators each include a moving electromagnet and a stationary permanent magnet.

[0011] In another example, a vibration device comprising a plurality of linear motion vibration actuators is operated by vibrating the actuators with similar frequency and phase. The amplitude of vibration of the actuators is controlled to achieve a desired direction of overall vibration force. For instance, the actuators may be vibrated with similar frequency and phase such that the maximum amplitude of vibration force occurs simultaneously in the linear motion vibration actuators.

[0012] In a further example, the vibration device comprises two linear motion vibration actuators such that the unit vectors are aligned with the direction of force created by the actuators to span a two dimensional space. Alternatively, the unit vectors need not be aligned with the direction of force created by the actuators and need not be parallel to each other.

[0013] In another example, a vibration device is comprised of three linear motion vibration actuators in which the unit vectors are aligned with the direction of force created by the actuators span a three dimensional space. A controller may be provided to synchronously vibrate these actuators.

[0014] A vibration device of another example comprises at least two linear motion vibration actuators where the unit vectors aligned with the direction of force created by the actuators span a two dimensional space. Alternatively, the unit vectors aligned with the direction of force created by the actuators may span a three dimensional space.

[0015] A vibration device comprising a plurality of vibration actuators may be configured so that the actuators are vibrated with similar frequency and phase such that the maximum amplitude of vibration force occurs simultaneously in the vibration actuators.

[0016] In another example, a vibration device comprises a plurality of vibration actuators attached to an enclosure of the vibration device and are synchronously vibrated. The actuators may be attached to a rigid component, a relatively rigid component, or a semi-rigid component of the vibration device.